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Abstract

Spontaneous combustion of residual coal in longwall goaf is a long standing hazard. Airflow leakage into goaf is a major driver to the hazard and this issue deteriorates where longwalls are operating in multiple seams and shallow covers because mining-induced cracks are very likely to draw fresh airflow into goaf due to presence of pressure differential between longwall face and surface. To study the problem more critically, a ventilation simulation package "Ventsim" is used to conduct a case study from Bulianta colliery. It was found that isolating and pressurizing active longwall panel can mitigate the problem and the pressure differential can be adjusted by varying performance of auxiliary fan and resistance of ventilation regulator. A booster ventilation system can also mitigate the problem by adjusting fan duties. Ventilation simulation is a powerful tool to study spontaneous combustion control in underground coal mine.

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Application of ventilation simulation to spontaneous combustion control in underground coal mine: A case study from Bulianta colliery



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ABSTRACT

Spontaneous combustion of residual coal in longwall goaf is a long standing hazard. Airflow leakage into goaf is a major driver to the hazard and this issue deteriorates where longwalls are operating in multiple seams and shallow covers because mining-induced cracks are very likely to draw fresh airflow into goaf due to presence of pressure differential between longwall face and surface. To study the problem more critically, a ventilation simulation package “Ventsim” is used to conduct a case study from Bulianta colliery. It was found that isolating and pressurizing active longwall panel can mitigate the problem and the pressure differential can be adjusted by varying performance of auxiliary fan and resistance of ventilation regulator. A booster ventilation system can also mitigate the problem by adjusting fan duties. Ventilation simulation is a powerful tool to study spontaneous combustion control in underground coal mine.

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1. Introduction

Coal, as a carbonaceous material, is capable of being oxidized and generating heat from ambient temperatures [1–4]. Self-heating or even spontaneous combustion of coal mass is likely to outbreak under favorable circumstances during many processes of coal extraction and utilization [2,5,6]. Especially underground coal mine fires have been identified as one of the most devastating mining hazards for posing a great threat to miners, burning out valuable coal mine assets, and giving off toxic and greenhouse gases [7,8]. Reviewing Australian coal mining history more than 125 fire incidents have been recorded in New South Wales whilst at least 68 incidents have been reported in Queensland from 1960 to 1991 and most of them occurred in underground workings [9]. From 1990 to 1999, approximately 17% of the 87 total reported fires for U.S. underground coal mines were caused by self-heating [10]. In India 75% of the coal mine fires occurs due to spontaneous combustion [11]. In China more than 50% of coal mines have had self-heating incidents and there are estimated to be 360 fire incidents each year caused by the spontaneous combustion within only several key coal mines [12]. A third of the 254 mine fires

reported during the period from 1970 to 1990 was caused by spontaneous combustion of coal in South Africa [13].

Generally several internal and external factors can contribute to spontaneous combustion of coal in underground coal mine [14]. Intrinsic factors like coal properties and geological conditions are beyond control of coal operators. While Extrinsic factors such as longwall (LW) panel layout, ventilation deployment, and mine planning can be managed by coal operators. Among those external factors ventilation arrangement is possibly of the utmost importance because airflow leakage into goaf from ventilation in LW working is a necessary element of fire. The primary duties of mine ventilation are to dilute hazardous accumulation of gas and dust, to dissipate heat primarily produced by mining machines, and to supply respirable air to underground working force [15–17]. A proper ventilation network is capable of fulfilling this duty in an economical means while a poorly managed ventilation system is very likely to fail the duty and even worse, to facilitate development of some mining hazards. Spontaneous combustion is one of them as coal mine ventilation is inevitably feeding oxygen rich air into longwall goaf where a significant amount of coal is left. Today there is a strong move to longer panels, wider faces, greater extraction heights, increased production rates, more efficient ventilation and decreased personnel in longwall coal mine [18]. The coal seams in newly developed mines or sections are generally thick and the risk of spontaneous combustion increases significantly during longwall mining due to the large quantities of broken coal

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left behind the chocks and its exposure to high oxygen levels in the goaf [19]. Due to depletion of the first coal seam, many coal mines in China have extracted the second seam or mined multi-seams simultaneously. The trending can now be found in Australian mining industry as well. It undoubtedly will pose more complexities to ventilation circuits and difficulties to manage coal spontaneous combustion because mining-induced cracks are more developed and more likely to propagate to surface to draw more air leakage for multi-seam LW operations. In exhaust ventilation system fresh air is drawn from surface to LW working face through the interconnected mining-induced cracks and vice versa for the force ventilation system. The pressure differential between LW working and surface is the major driver for the leakage, so minimizing the pressure differential is another important duty of ventilation for LWs operated in multiple coal seams and under shallow cover. A popular philosophy in dealing with spontaneous combustion hazard is prevention is always better than cure. Although many advances in gas monitoring techniques, sealing and stopping construction, and proactive inertisation plan have been achieved, a more competent ventilation system which can reduce the leakage into goaf is the first and also the most important shield to the hazard. To quantify the pressure differential and investigate the issue with more details, a ventilation simulation program called “Ventsim” is used to perform a case study based on a real ventilation network of Bulianta colliery. The colliery is one of the most productive LW operations in China and also a very representative LW operated in multiple coal seams and under shallow cover.

2. Project description

2.1. General introduction

Bulianta colliery is situated 13 km south to Ordos city of Inner Mongolia Autonomous Region of Northern China (see Fig. 1). The colliery is operated in Shendong coalfield which is featured with flat and thick coal seam under shallow cover. Mining area of the colliery is approximately 34 km² and the total proven reserve exceeds 506 million tons of coal. Due to recent upgrade of mining technology and equipment, extraction height of LW working face has increased to 7 m and annual production of the coal mine has exceeds 15 million tons of coal. Bulianta colliery and several other coal mines in Shendong coalfield have become the most productive underground LW operations in China.

2.2. Geological conditions

According to the data interpretation of drilling core, the outcrop of strata and the proven geological information of the coalfield, the stratigraphy of the colliery is estimated. Fig. 2 shows a simplified

distribution of the strata. Main extraction coal seam 1⁻² seam is located in upper part and the other two main seams 2⁻² and 3⁻¹ seam are distributed in middle part. The average thicknesses of three coal seams are 4.1 m, 6.8 m, and 3.2 m respectively. Spacing of them is approximately 32 m between 1⁻² seam and 2⁻² seam and 28 m between 2⁻² seam and 3⁻¹ seam, respectively. The mining region is part of the Ordos early-middle Jurassic coal bearing basin and no big faults are found in the basin. The basin is developed in the platform on the basis of inheriting type basin in which the strata lies towards the N20° to 30°W and the tendency is S60°–70°W. The incline of the strata varies slightly from 0° to 3° and the floor of coal seam has slight fluctuation with gentle lift in the east. It is noticeable coal seams in this colliery are closely distributed and operated under very shallow cover.

2.3. Problem identification

Currently the coal mine is extracting two coal seams, namely 1⁻² coal seam and 2⁻² coal seam. 3⁻¹ coal seam is on standby. Fig. 3 shows the overall layout of Bulianta coal mine. The whole mine is divided into five sections with several longwall panels within each of section. 1⁻² coal seam and 2⁻² coal seam has been totally extracted in section one and two. At present section four and section five are mining 1⁻² coal seam and section three is mining 2⁻² coal seam as 1⁻² coal seam has been extracted and it is believed overlying goaf has been interconnected via mining-induced cracks. Contaminated air is taken out of pit via two main exhaust fans. One is installed in north exhaust shaft and another one is installed in south exhaust incline. Fresh air is mainly taken from intake incline and intake shaft (see Fig. 3). Intake shaft serves to section five and main intake inclines serves to section three. Fresh air is supplied from both intake shaft and intake incline for section four.

Since the commencement of extraction of panels in section three, several serious coal oxidation and self-heating incidents have occurred and culminated in one open fire incident at LW22306 working panel (see Fig. 3). It was found the fire originated from overlying 1⁻² coal seam goaf because high concentration of CO (exceeds 10,000 × 10⁻⁶) was initially detected from several boreholes drilled to overlying 1⁻² coal seam goaf. The fire caused closure of the panel for more than six months and costed hundreds of millions of dollars to quench it by slurry injection through hundreds of downholes. After undertaking investigation and incident review, the possible reason of the occurrence of the fire incident was revealed and can be illustrated in Fig. 4. As is widely accepted, a major consequence of coal extraction is ground subsidence and creation of fractures and cracks to the overlying or underlying strata. In this case, after 1⁻² seam was mined, the induced cracks may have already developed to surface due to shallow cover of the coal seam. As 2⁻² coal seam was further extracted, more developed and wider cracks were likely to be induced because of higher mining height of this coal seam. These channels are very likely to become interconnected and propagate to surface. Fig. 5 presents real images of mining-induced cracks developed to surface. These channels can function as air leakage path from surface to active working face if any pressure differential presents. As this mine is currently using an exhaust ventilation method, the pressure of the airflow in working face is possibly much lower than surface atmospheric pressure. Therefore, the pressure differential is very likely to draw a certain amount of fresh air from surface to active longwall face through these channels. In addition, the immediate roof of Shendong coalfield is very fragile, and as a result, approximately 0.5 m top coal is reserved to facilitate chock support and will be left in goaf as LW advances. With continual supply of fresh air, smoldering of coal developed to an open fire as the heat generated from coal oxidation is not sufficiently dissipated. The pressure differential not only aggravates the self-heating process



Fig. 1. Location of Bulianta colliery.

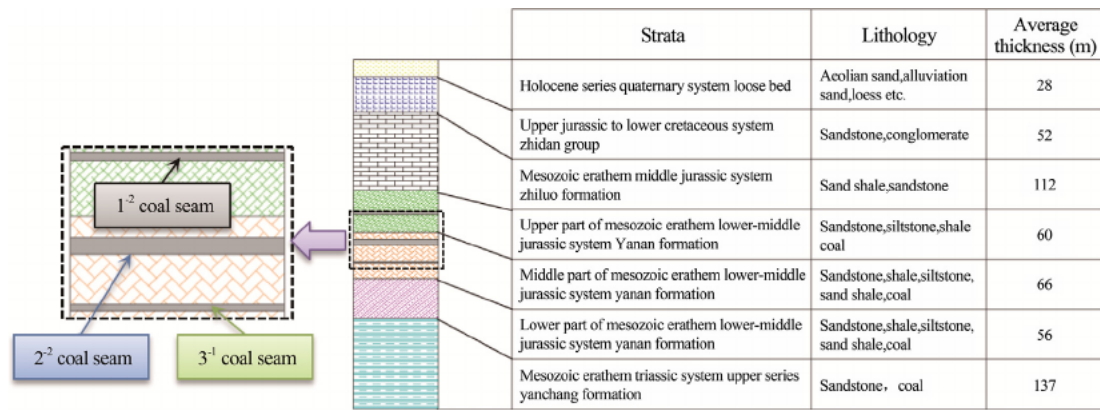


Fig. 2. A simplified stratigraphy of Bulianta colliery.

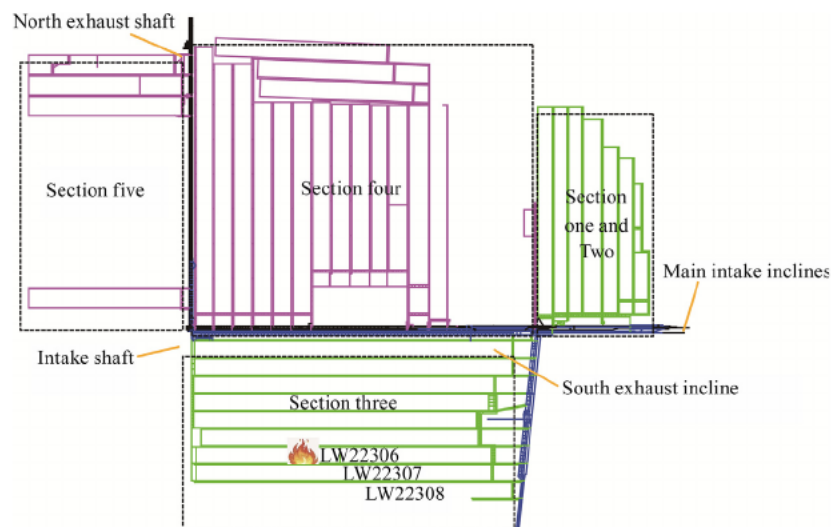


Fig. 3. Overall layout and ventilation network of Bulianta colliery.

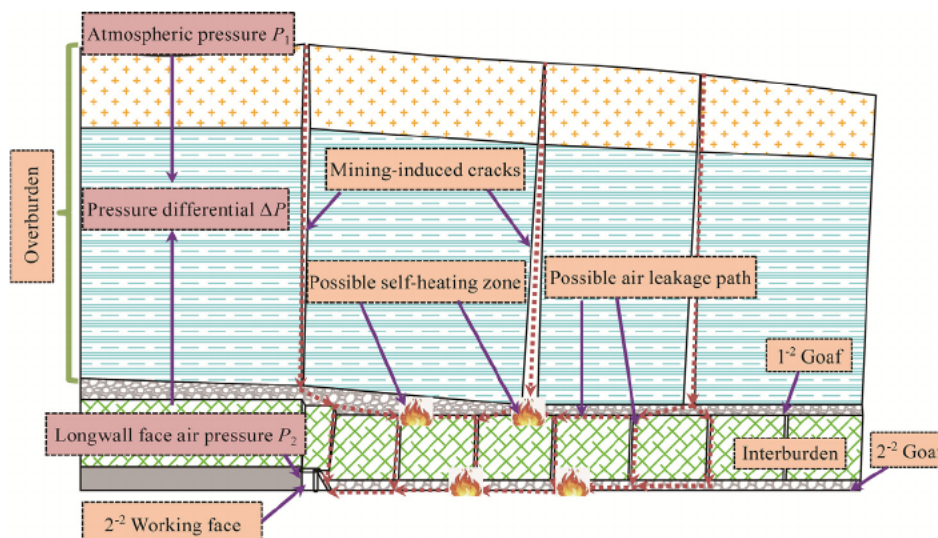


Fig. 4. Schematic illustration of the occurrence of fire incident at Bulianta colliery.

of coal but also promotes the ingress of goaf gas into the working face. The ingress of oxygen deficient and high concentration of CO gas poses a great threat to the safety of working crew at longwall

face. Many practices have been exercised to control the problem. One direct solution is to seal these cracks with grout or slurry injection. However, the solution is still prohibitive for two reasons.



Fig. 5. Two photographic views of mining-induced cracks at Bulianta colliery.

One is the cost would be substantial as there are a large number of cracks required to be treated. Another difficulty is many concealed cracks are hard to be detected. Therefore, minimizing the pressure differential between surface and ventilation circuit by improving ventilation performance would be a promising solution and this is also an important initiative of this project.

3. Development and validation of “Ventsim model

A rational solution to the air leakage through mining-induced cracks is to minimize the pressure differential between surface and ventilation circuit. To quantify the pressure differential and to investigate this issue more critically, a ventilation simulation program “Ventsim” is used to conduct the case study. “Ventsim” is one of the most sophisticated software packages in underground mine ventilation simulation and is widely used in many Australian underground mining operations. “Ventsim” can be utilized to assist a range of mine ventilation related operations including mine ventilation design, mine network analysis and optimization, prediction of recirculated ventilation, and economical analysis on mine ventilation.

3.1. Model development

Geometric model is established by importing Autocad DXF file which incorporates the real plan map of the whole mine. After a complex DXF drawing is imported to “Ventsim”, it is very likely disconnected or overlapping airways are incorporated within raw model data. It is necessary to run geometry repair or simplification before editing any airway. After tidying up the model, the next step is to assign various parameters including airway profile, geometric dimension, and frictional factor to every single airway. In addition, proper resistance factors should also be assigned to ventilation control devices like airlocks, belt seals, and ventilation air doors. Editing of airways can be accomplished by accessing into edit box (see Fig. 6). Then two exhaust fans are installed at main exhaust incline and north exhaust shaft, respectively. In this application two main exhaust fans curve are interpolated by seven data points based on site measured fan curve data (see Fig. 7). Fig. 8 shows an overview of the established base model.

3.2. Model validation

The base model is validated through two steps. One is via quantity of airflow at most of the important locations and another one is to check pressure loss along critical ventilation paths. Fig. 9 compares the site measured air flow quantity of critical locations with the computed data and it can be seen the differential is marginal. Bulianta colliery undertook a comprehensive ventilation survey in 2013 and the survey was performed along three airflow paths,

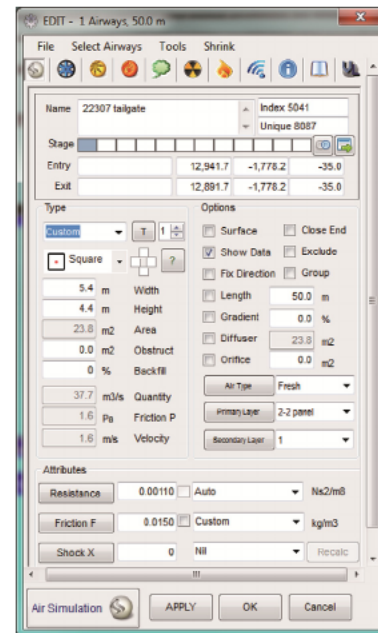


Fig. 6. Airway parameter editing dialog box in “Ventsim”.

namely LW22305 path, LW12409 path, and LW12519 path. The three paths represented three panel sections (section three, section four, and section five, respectively) and the pressure loss is validated through the three paths. The detail of the validation is only presented at section three as LWs in section three are the most risky area in terms of coal spontaneous combustion and ingress of goaf gas. The follow-up studies will focus on LW22307 path as well. Fig. 10 is a simplified airflow path through LW22307. Most fresh air is taken from main intake incline and then directs to 2⁻² coal seam intake main. Part of the fresh airflow in 2⁻² seam intake main is taken to section three longwalls via section three intake main. Then fresh air in LW22307 is supplied through both LW22307 maingate and LW22308 tailgate. Contaminated air is drawn to section three exhaust main via LW22307 tailgate and it is then delivered to 1055 level exhaust main before the contaminated air is discharged through fan at south exhaust incline. Fig. 11 shows the validation of pressure loss along LW22307 path. It can be seen the overall trend of it resembles that of measured LW22305 path. It underwent a slight increase of pressure loss comparing to that of LW22305 path due to its longer flow path and the major of pressure loss occurs at exhausting airways. It can be also observed at working face the pressure loss exceeds 200 Pa and as a result, the pressure differential between working face and surface is more than 200 Pa. A large amount of fresh air will be attracted

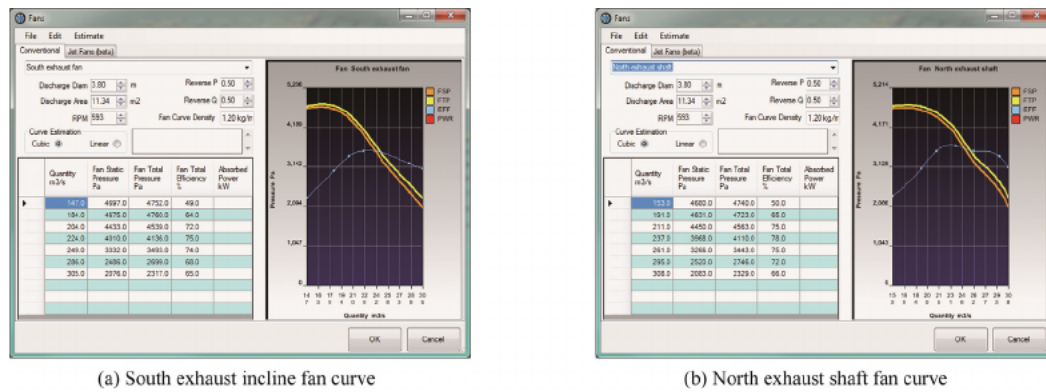


Fig. 7. Fans installation at south exhaust incline and exhaust shaft.

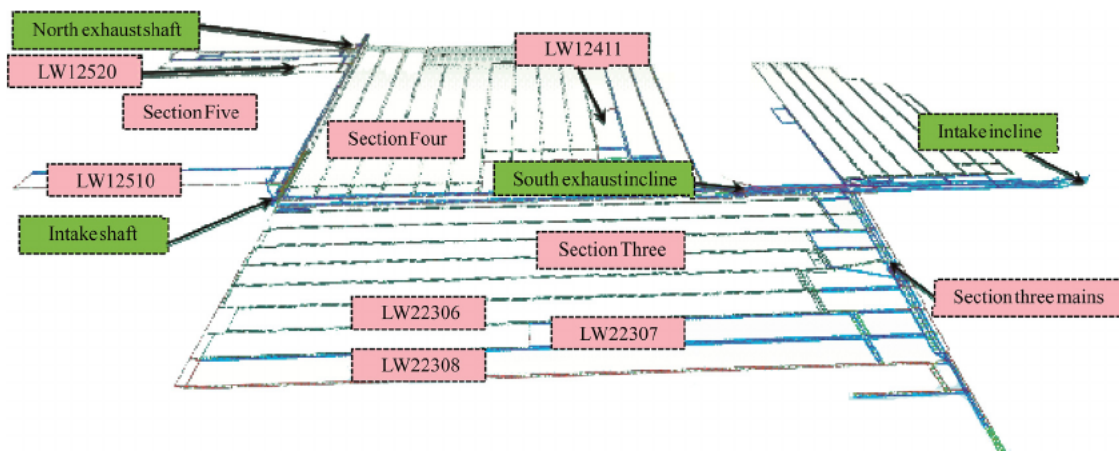


Fig. 8. Overview of the base model in "Ventsim". Airways in blue colour represent fresh airflow intake, airways in red colour stands for exhaust airflow, and black colour denotes sealed airways or virtual fringe of LW goaf.

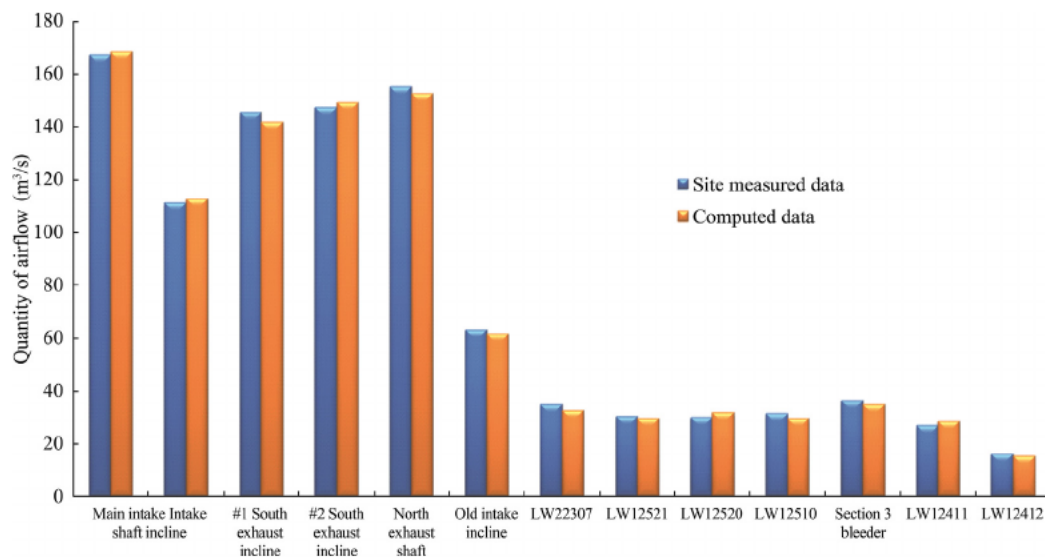


Fig. 9. Comparison of site measured airflow quantity with computed data at critical airways.

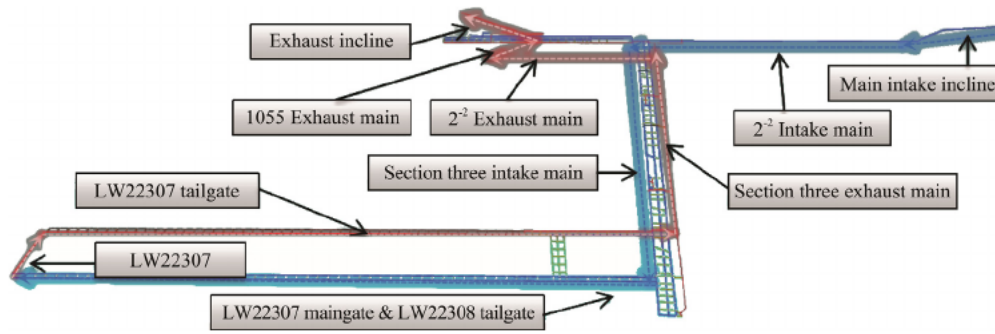


Fig. 10. Simplified airflow path of LW22307.

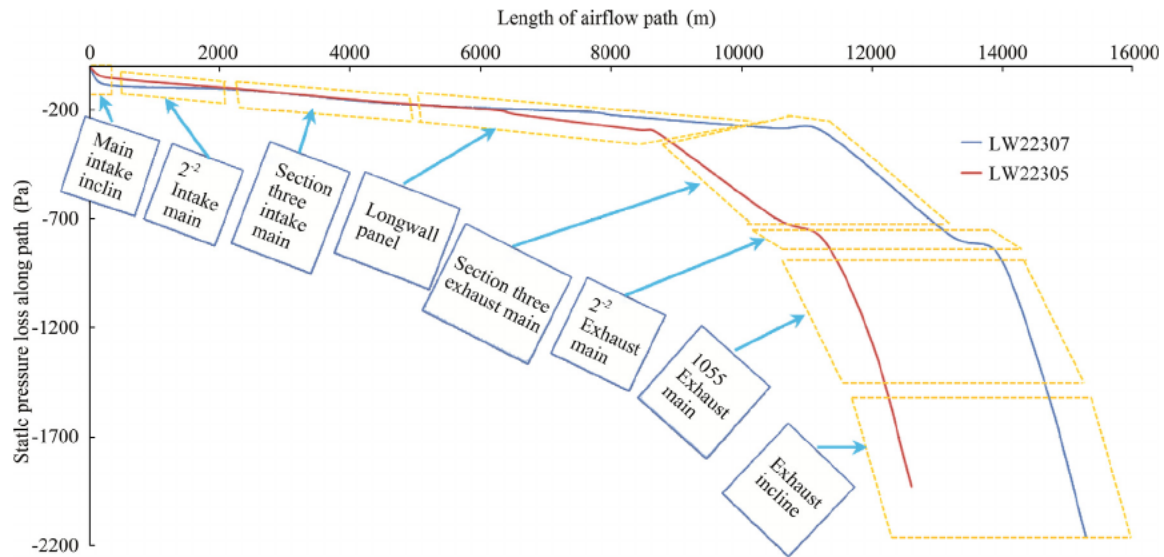


Fig. 11. Validation of pressure loss along LW22307 airflow path.

into LW working face once mining-induced channels propagate to surface due to presence of the 200 Pa pressure differential. This pressure differential also provokes migration of goaf gas into working face and poses immediate danger to underground miners.

4. Solutions and discussion

4.1. Possible solution one: Modify ventilation network within panel

It has been studied different ventilation modes within LW panel may induce different pressure differential across LW face and therefore affect air leakage into goaf [18,20]. To reduce pressure differential along LW22307 face, the first possible measure is to modify ventilation network within panel. In this study, total seven scenarios are proposed and analyzed (see Table 1). The results of the simulation are presented in Figs. 12 and 13.

Fig. 12 depicts the pressure loss paths of various ventilation modes within panel. It can be seen the pressure differential is not able to be eliminated. The pressure differential at face shows little difference except for two Bleederless ventilation modes. To meet comfortable working conditions at LW face, no less than 30 m³/s fresh air is required in this colliery. As can be seen from Fig. 13, “Homotropical U” and “Bleederless homotropical U” are clearly not suitable due to low quantity of airflow across LW22307 even though “Bleederless homotropical U” can slightly reduce the pressure differential. “Bleeder return” and “Double return” ventilation modes are able to supply sufficient air to working face but the

pressure differentials become greater than that of on-site ventilation mode. “Bleederless on-site U” can considerably reduce the pressure differential but the airflow quantity is slightly less than the requirement. In addition, Bleederless ventilation network would increase overall resistance and therefore it is inappropriate to be used for a long period of time. No matter how the mode of network is modified, the pressure differential would not be eliminated. It is an intrinsic flaw for exhausting ventilation network. Once mining-induced cracks develop to surface, fresh air will always be drawn to working face and vice versa for a forcing ventilation system.

4.2. Possible solution two: Pressurize LW panel

To decrease pressure differential and meanwhile to deliver sufficient fresh air to LW working face, a solution called pressurizing LW panel is proposed. The essence of the solution is to provide a positive pressure at the start of panel intake to offset the pressure lost in the past airways. To achieve the positive pressure, an auxiliary fan and several ventilation control devices are required (see Fig. 14). Fig. 14 shows a possible deployment plan to pressurize LW22307. At the start of the panel intake, an auxiliary fan is installed at one LW22308 recovery roadway and a ventilation regulator is installed at one cut-through between LW22306 maingate and LW22307 tailgate to adjust the pressure and airflow. The ventilation regulator is essentially a ventilation door with adjustable opening. Fig. 15 shows the pressure loss trend along ventilation

path with varying resistance factor and fan duty. It is noticeable pressurizing LW22307 working face would considerably reduce pressure differential and in addition, ideally true balance could

be acquired by adjusting the resistance factor or fan duty. Fig. 16 shows pressure differential and airflow quantity across LW22307 with varying resistance factor (R) and auxiliary fan duty

Table 1

Different ventilation modes of LW22307. Blue lines denote fresh airflow, red lines denote contaminated air flow, and green lines denote isolated or sealed airways.

Scenario	Illustration	Notes
On-site U		Fresh air is taken from both LW22307 maingate and LW22308 tailgate while contaminated air return to LW22307 tailgate and then LW22306 maingate
Homotropical U		Fresh air is taken from LW22308 tailgate and allows for a split of air return to LW22307 maingate. The rest of the air returns to LW22307 tailgate after passing working face
Reverse U		Inverse to the on-site U mode, fresh airs is taken from LW22307 tailgate and polluted air returns to LW22307 maingate
Bleederless on-site U		Section three bleeder is sealed. Fresh air is provided from LW22307 maingate and LW22308 tailgate. Most of the contaminated air returns to section three exhaust main through LW22307 tailgate and rest of the polluted air returns through LW22308 panel
Bleederless homotropical U		Section three bleeder is still sealed and fresh air is taken to LW22307 via LW22308 tailgate. A part of air is directed to return at the in by split location and another part of fresh air flow through LW22307 face to LW22307 tailgate and LW22306 maingate

(continued on next page)

Table 1 (continued)

Scenario	Illustration	Notes
Bleeder return		Fresh air is taken from LW22307 tailgate and dusty air is directed to LW22308 tailgate and back return to section through bleeder
Double return		Similar to bleeder return mode, fresh air is taken from LW22307 tailgate. Air return both from LW22307 maingate and section three bleeder

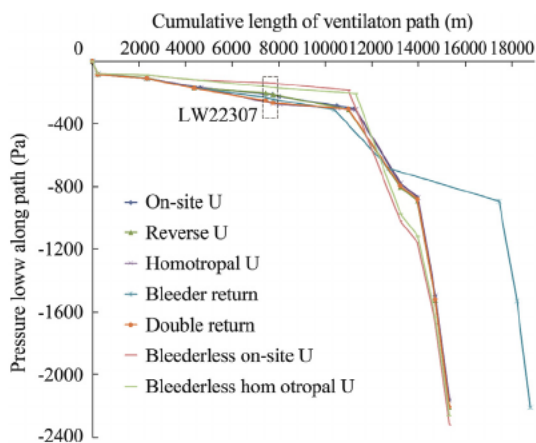


Fig. 12. Ventilation pressure loss paths of various ventilation modes.

(F). It is obvious airflow quantity across LW22307 would increase with more powerful fan and/or less resistance from ventilation regulator. The pressure differential evolves from negative to positive with more powerful fan and/or more resistance from ventilation regulator, and therefore, ideally a neutral point where there is no pressure differential can be extrapolated. However, maintaining LW panel pressure slightly positive is conducive to contain toxic gas within goaf hence improving working conditions at LW working face.

4.3. Possible solution three: A booster ventilation system

Instead of locally isolating and pressurizing LW22307 panel, utilization of a booster ventilation system (Blower-Exhaust) can initially provide airflow with a positive pressure to overcome the pressure loss along ventilation path before airflow arrives at LW22307 working face. The mechanism can be explained in Fig. 17. For an exhaust ventilation system, neutral point locates at start of the intake opening and the negative pressure grows along path and reaches peaks at fan. While for a force system, at intake fan provides airflow with a positive pressure to overcome the pressure loss along path and neutral point lies at the end of the ventilation path. The booster ventilation system takes advantages of the two previous systems and the neutral point can be

adjusted to any point in the middle of the ventilation path. By this way the pressure differential between LW face and surface can be significantly reduced. Therefore, the performance of a booster ventilation system is simulated with varying fan duties and the results are shown in Figs. 18 and 19.

A forcing fan with similar capacity is installed at intake incline and several other openings are regulated with air locks by increasing magnitude of resistance factor. The solution is demonstrated by various duties of two fans and the result is illustrated in Figs. 18 and 19. From Fig. 18, it can be observed airflow is given a positive pressure initially by the forcing fan to offset the pressure loss along path. The pressure differential significantly decreases if fan dust is adjusted properly. The neutral point can move to any point by manipulating fan duties. As can be seen in Fig. 19, it is obvious the airflow quantity reduces slightly with fan duty dropping but the pressure differential is very sensitive to fan duty. Ten percent alteration of fan duty may have dramatically changed the pressure differential across LW face.

4.4. Discussion

If whole mine ventilation system is governed by only exhausting or forcing system, the pressure differential would not be eliminated no matter how the network is modified. Bleederless ventilation system may improve the problem but increase difficulty of ventilation and may cause even more pressure differential at other return airways. Hence, solution one is not suitable at least for long term operation. Pressurizing LW panel can tackle both the problems including sufficient air supply and less pressure differential at LW face. The two parameters are adjustable with varying auxiliary fan duty and resistance factor of ventilation control device. The major flaw of this method is as follows. In case auxiliary fan fails, goaf toxic gas would migrate instantly to working face and pose a great danger to working crew. Therefore, extra precautions and sufficient risk assessments must be put in place before the implementation of this solution. With more and more LWs trending to be operated in underlying coal seams, a booster ventilation system may find its rationale because it is less complex than locally isolating and pressurizing a LW panel. In addition, this system has fewer disturbances to production operation comparing to balancing pressure differential of LW panel one by one. However, additional capital and operational cost is incurred by installing and running extra fans and in addition, all mine accesses

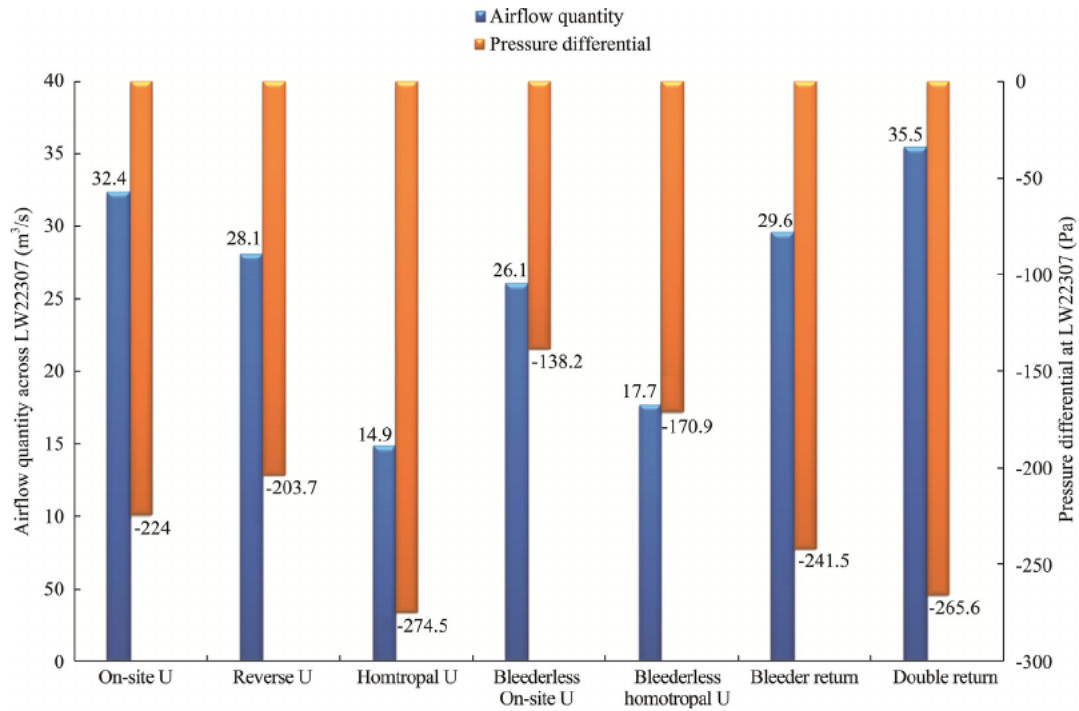


Fig. 13. Pressure differentials and airflow quantities across LW22307 of different ventilation modes.

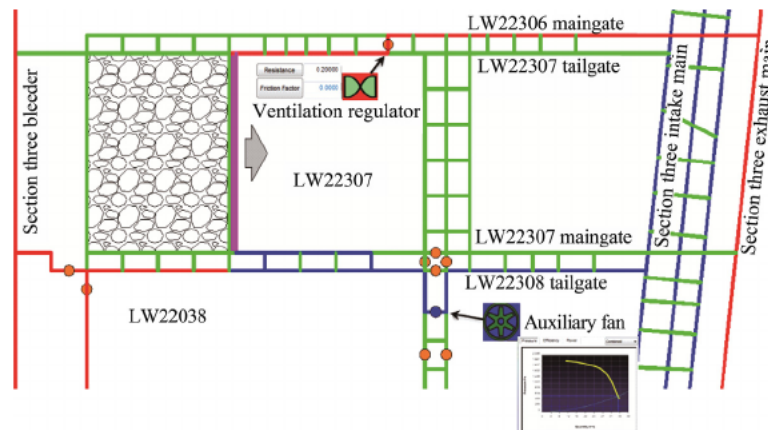


Fig. 14. Schematic illustration of isolating LW22307 panel with positive pressure.

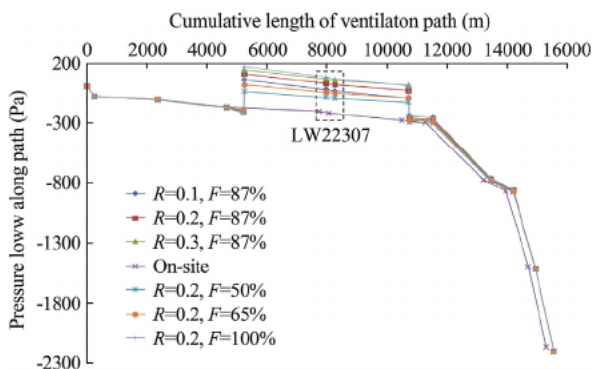


Fig. 15. Pressure loss paths with varying resistance factors and auxiliary fan duties.

need to install airlocks or conveyor seals. For an on-going LW operation in multi-seam, pressurizing LW panel might be a better

option to minimize pressure differential and air leakage to goaf. A booster ventilation system should receive more considerations upon planning an underground mining operation as this system has less interference to production mining operations.

5. Field demonstration

LW22307 of Bulianta colliery commenced the operation on July, 2014. Initially the ventilation system used within the panel is purely exhausting and no measures have been taken to mitigate potential fire occurrence although a fire incidence has occurred in adjacent goaf. With the detection of several possible self-heating developments and growing severity of ingress of oxygen deficient gas into working face, the mine determined to pressurize the LW panel (solution two) to reduce the air leakage at the end of 2014. After reviewing the failure modes and conducting risk assessments, an auxiliary fan was employed to provide the positive pressure and associated ventilation regulators were also

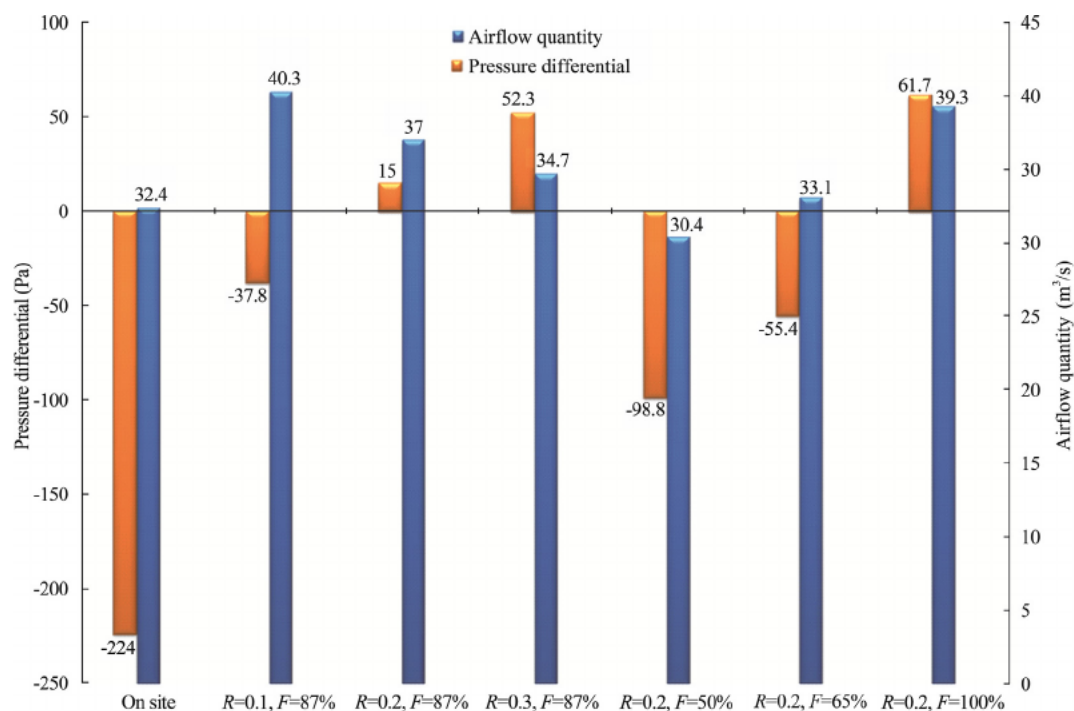


Fig. 16. Pressure differential and airflow quantity across LW22307 with varying resistance factors and auxiliary fan duties.

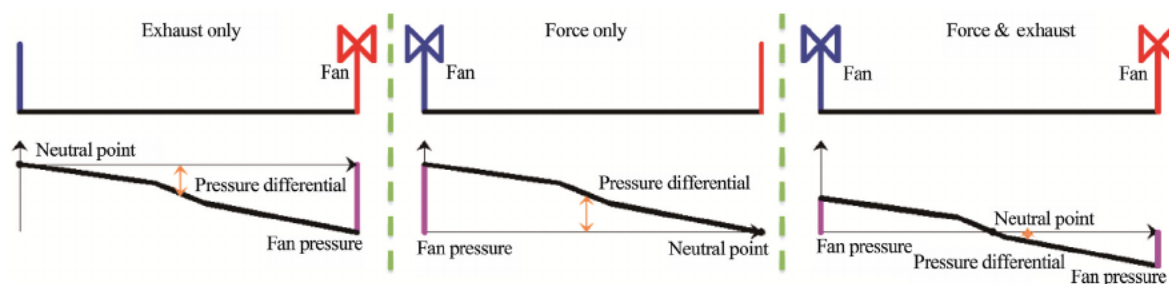


Fig. 17. Schematic view of pressure loss along path of three ventilation systems.

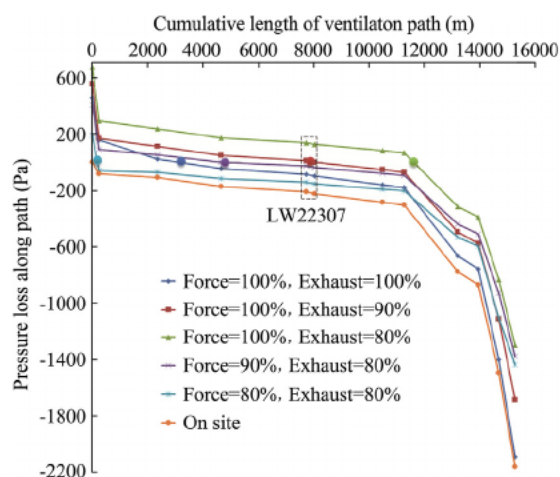


Fig. 18. Pressure loss paths with varying fan duties of the booster ventilation system.

constructed to adjust the pressure and airflow across working face (see Fig. 14). Quantity of air leakage and gas composition at LW

face were continually monitored after excising this control measure. As can be seen from Fig. 20, quantity of airflow across working face underwent a slight growth and the airflow leakage from goaf was substantially reduced after balancing the pressure differential. Fig. 21 shows gas monitoring data of a sampling point at conjunction of working face and LW22307 tailgate. The oxygen concentration increased considerably and an inverse trend was found for the nitrogen concentration. Goaf gas ingress was constrained and the working conditions were greatly improved after the control was exercised. Therefore, locally pressurizing LW panel is concluded as an effective measure to control pressure differential and spontaneous combustion hazard for an on-going LW operation with exhausting ventilation system.

As this mine is an on-going operation, the large ventilation system is unlikely to be changed during extraction of LW22307 panel. Therefore, demonstration of solution three in Bulianta colliery is impossible to be accomplished. However, this method has been successfully used in a LW operation in Hunter Valley, Australia [9]. This coal mine is also operated in multi-seam and shallow cover, which resembles the LW operation in Bulianta colliery. Hence if LWs are operating under alike conditions (shallow cover or multiple coal seams which are closely distributed), a booster ventilation system could be a better solution as it is less complex

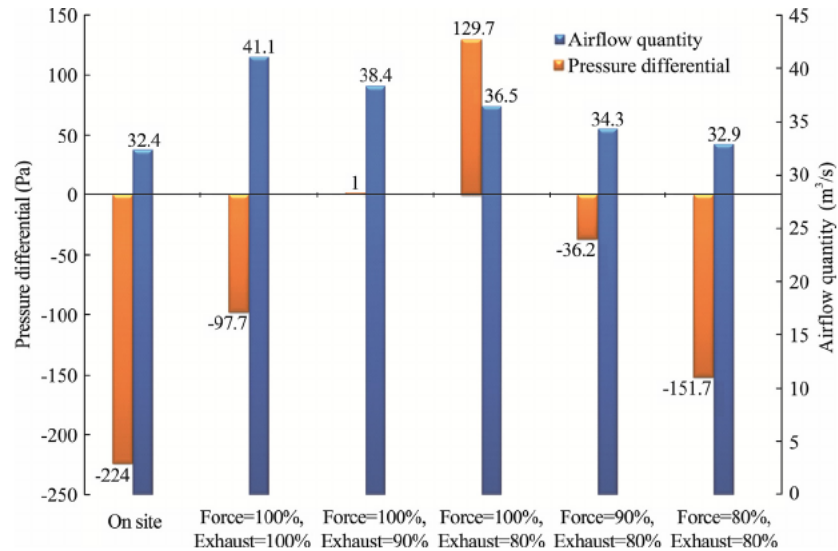


Fig. 19. Pressure differential and airflow quantity across LW22307 with varying fan duties of the booster ventilation system.

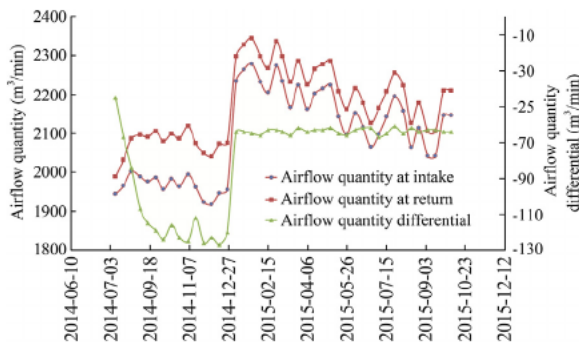


Fig. 20. Comparison of airflow leakage before and after pressurizing LW22307 at Bulianta colliery.

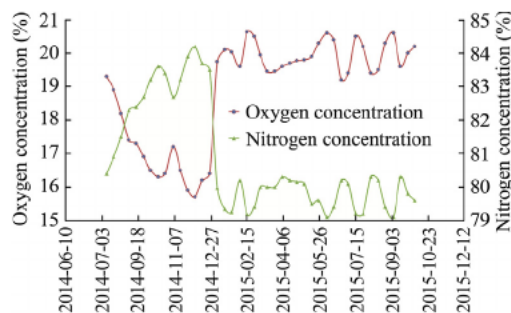


Fig. 21. Comparison of oxygen and nitrogen concentration at conjunction of LW and return before and after pressurizing LW22307 at Bulianta colliery.

and more flexible to adjust the neutral point. Clearly this requires more demonstrations and field trials to benchmark the solution.

6. Conclusions

In this paper, a ventilation simulation package “Ventsim” is used to undertake a case study to investigate air leakage problem in LW operated in multi-seam and under shallow cover. After development and calibration of the base model, three solutions are proposed to mitigate the pressure differential issue. The following conclusions are drawn:

- (1) Pressure differential between LW face and surface is an intrinsic flaw if a purely exhausting ventilation system is used in a mine. The pressure differential is not able to be eliminated no matter how the ventilation circuit is modified.
- (2) Isolating and pressurizing active LW panel can provide working face sufficient amount of fresh airflow and meanwhile reduce pressure differential. This is accomplished by deployment of an auxiliary fan and several ventilation regulators. Ideally the pressure differential can be removed if the resistance factors of ventilation control devices and duty of auxiliary fan are adjusted properly. This solution was justified in Bulianta colliery.
- (3) Extra precautions and sufficient risk assessments must be put in place before locally pressurizing LW panel because a large amount of goaf toxic gas would instantly strike working face and pose a great danger to working crew in case auxiliary fan fails. This solution is more suitable to an ongoing LW operation.
- (4) A booster ventilation system (Blower-Exhaust) can also reduce the pressure differential by adjusting duties of the two main fans. Theoretically the neutral point can be distributed any location along the pressure loss path by manipulating performances of two fans. The solution has been demonstrated in a LW operation in Australia.
- (5) The booster ventilation solution is more recommended for LW operations in planning as this system has fewer disturbances to production operation comparing to solution two. However additional capital and operational cost is imposed by installing and running extra fans and in addition, all mine accesses need to install ventilation control devices.
- (6) No doubt ventilation simulation is a powerful tool to study spontaneous combustion issues in underground coal mines.

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